Radiation Basics

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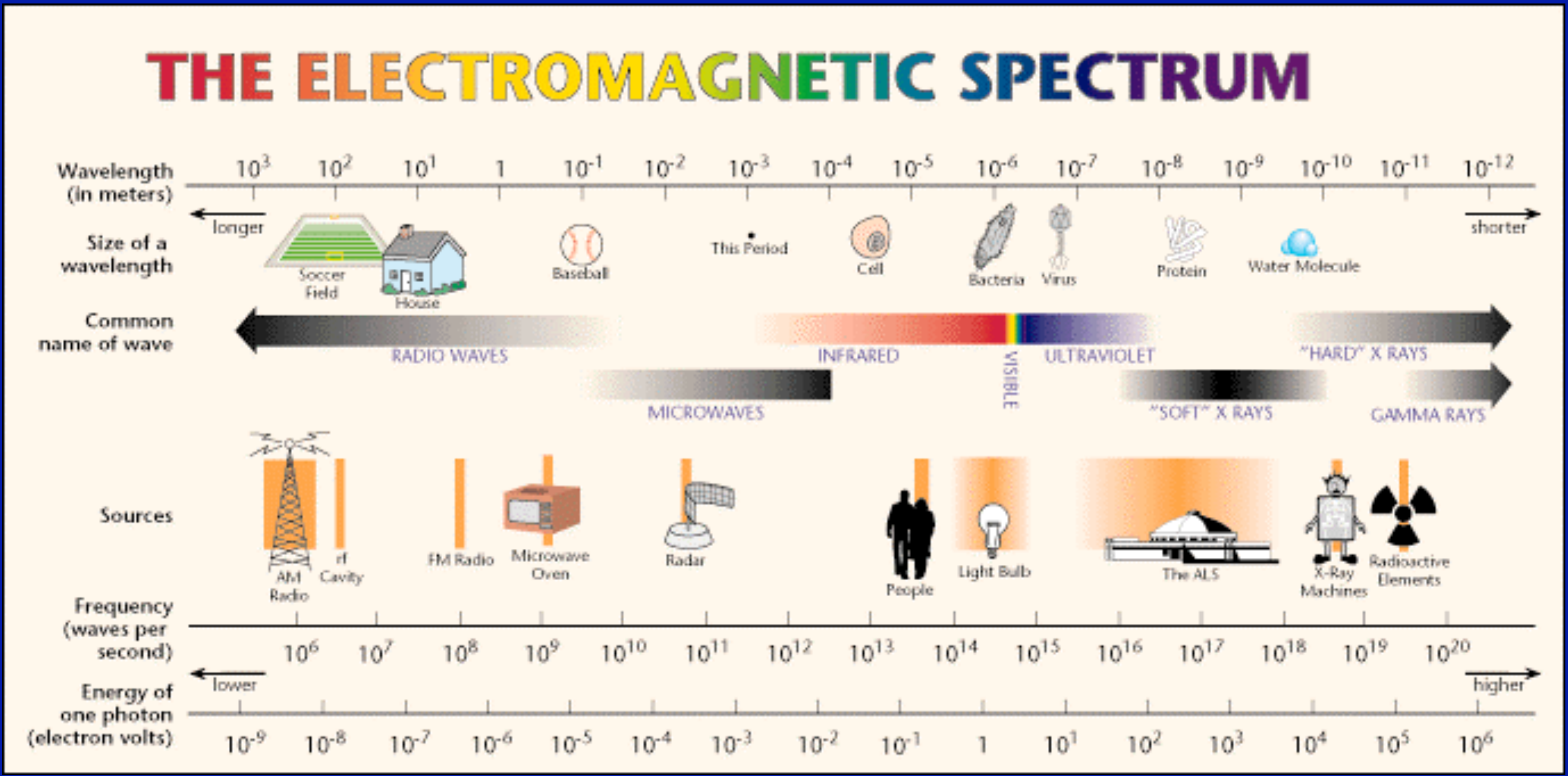
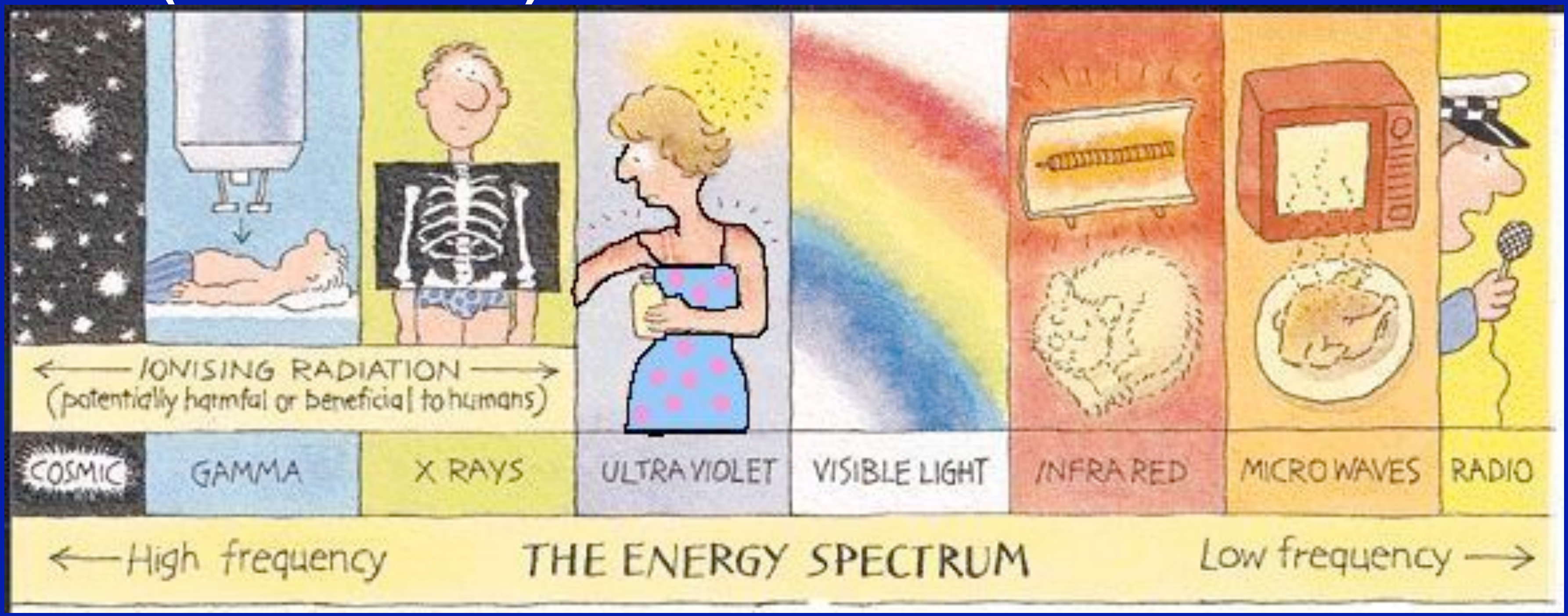
RADIATION
Need Not Be
FEARED
But it MUST
COMMAND YOUR
RESPECT.
HEALTH PHYSICS For Your Protectio

Electromagnetic Spectrum



Radiation is Energy

- **The energy is given off by unstable (radioactive) atoms and some machines.**



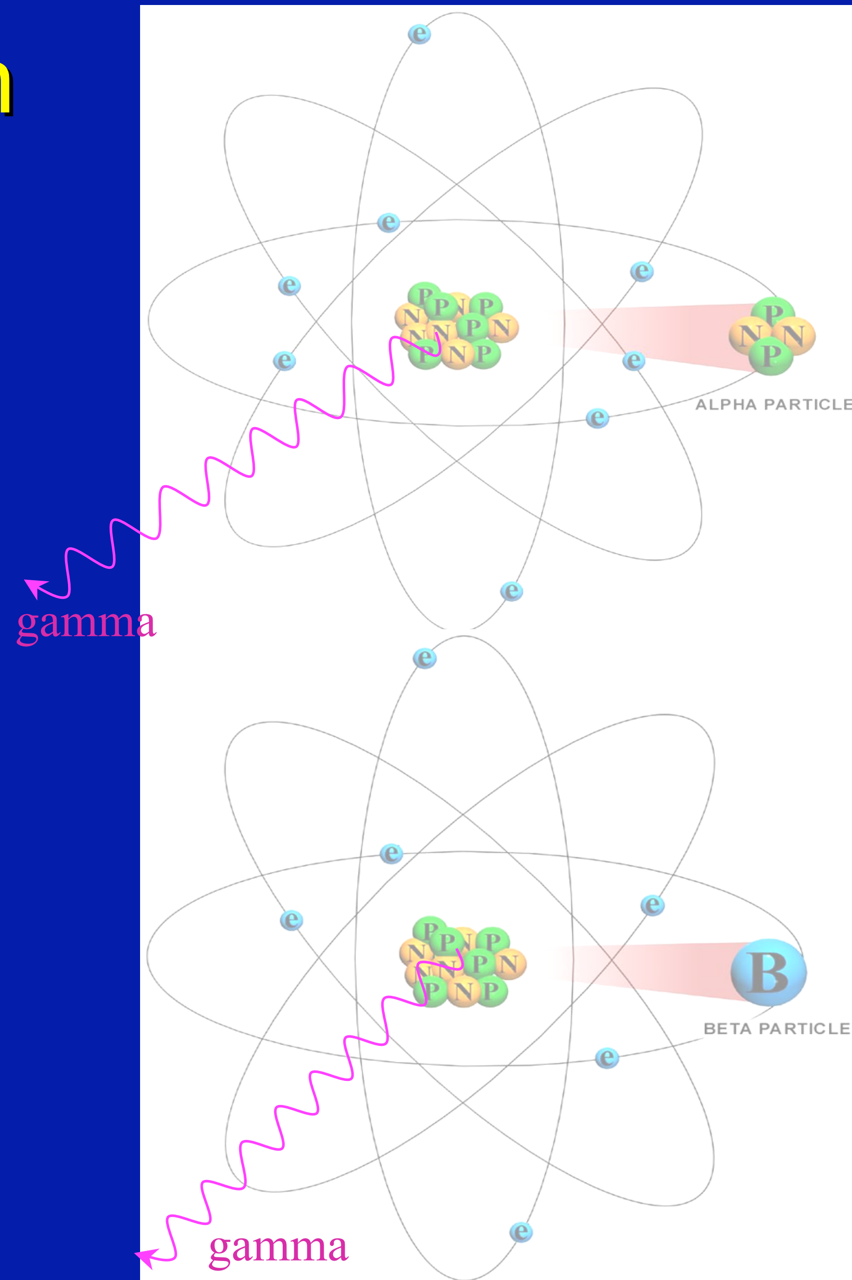
- **For this talk, we will be focusing on <u>ionizing radiation</u>**

Radiation and Radioactive Material are a Natural Part of Our Lives

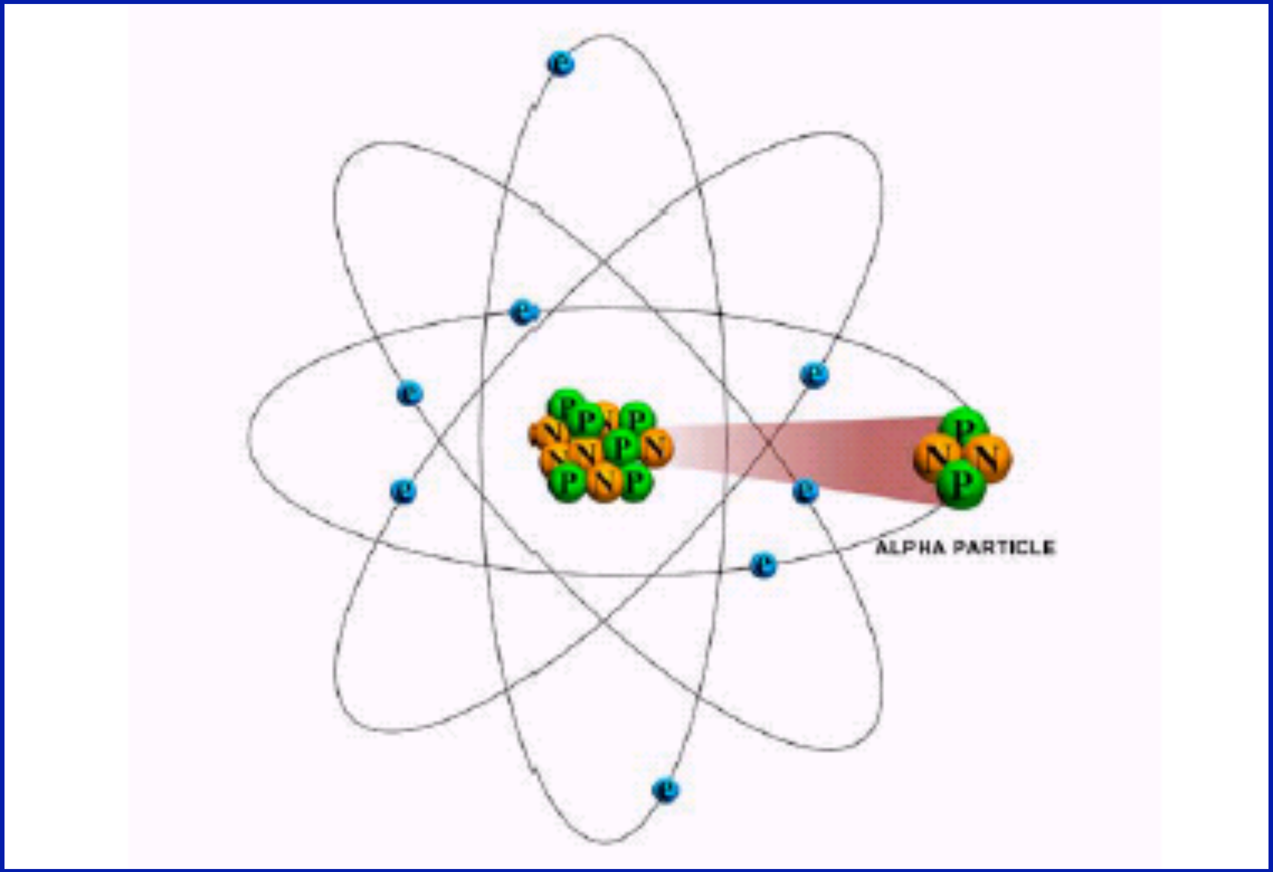
- We are constantly exposed to low levels of radiation from outer space, the Earth, and medicine.
- Low levels of naturally occurring radioactive material are in our environment, the food we eat, and in many consumer products.
- Some consumer products also contain small amounts of man-made radioactive material.

Forms of Radiation

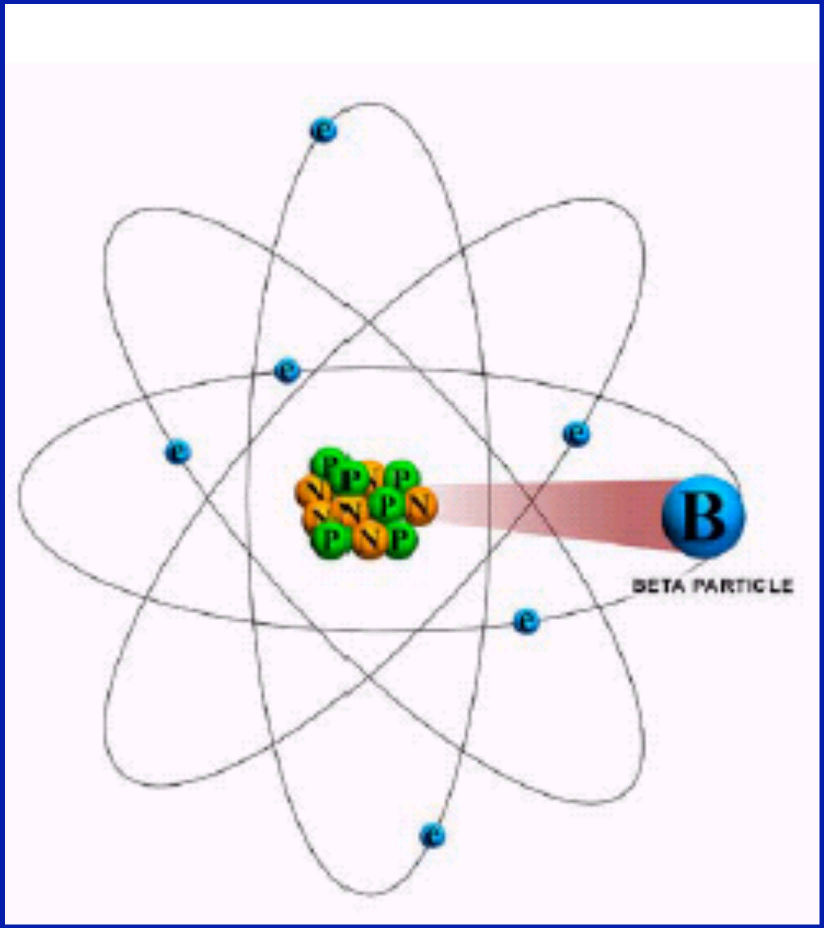
- When unstable atoms transform, they often eject particles from their nucleus. The most common of these are:
  – Alpha Radiation
    High energy, but short range (travels an inch in air, not an external hazard)
  – Beta Radiation
    Longer range (10 – 20 feet in air) and can be a skin and eye hazard for high activity beta sources.
- Gamma Rays (electromagnetic radiation)
  Often accompany particle radiation. This “penetrating” radiation is an external hazard and can travel 100s of feet in air.



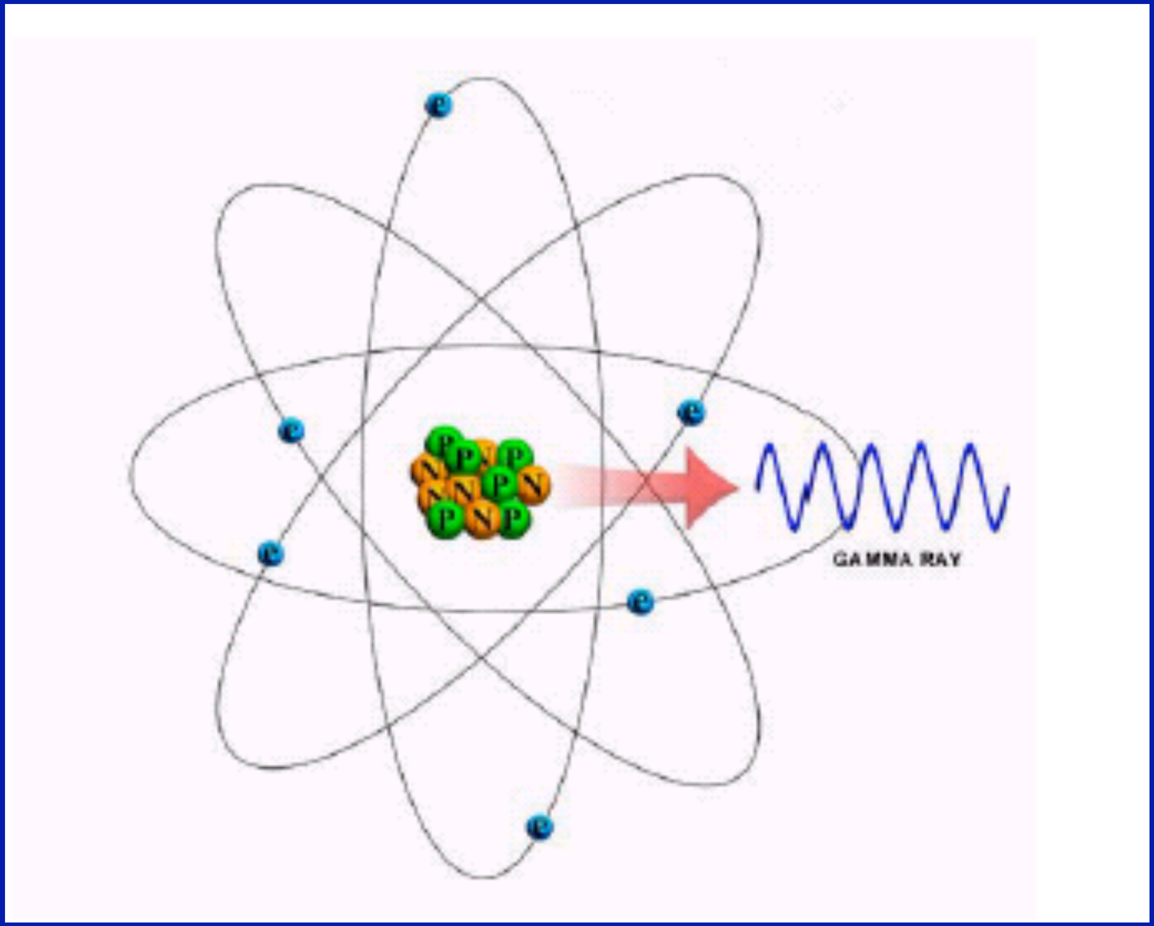
Alpha Particle (α)



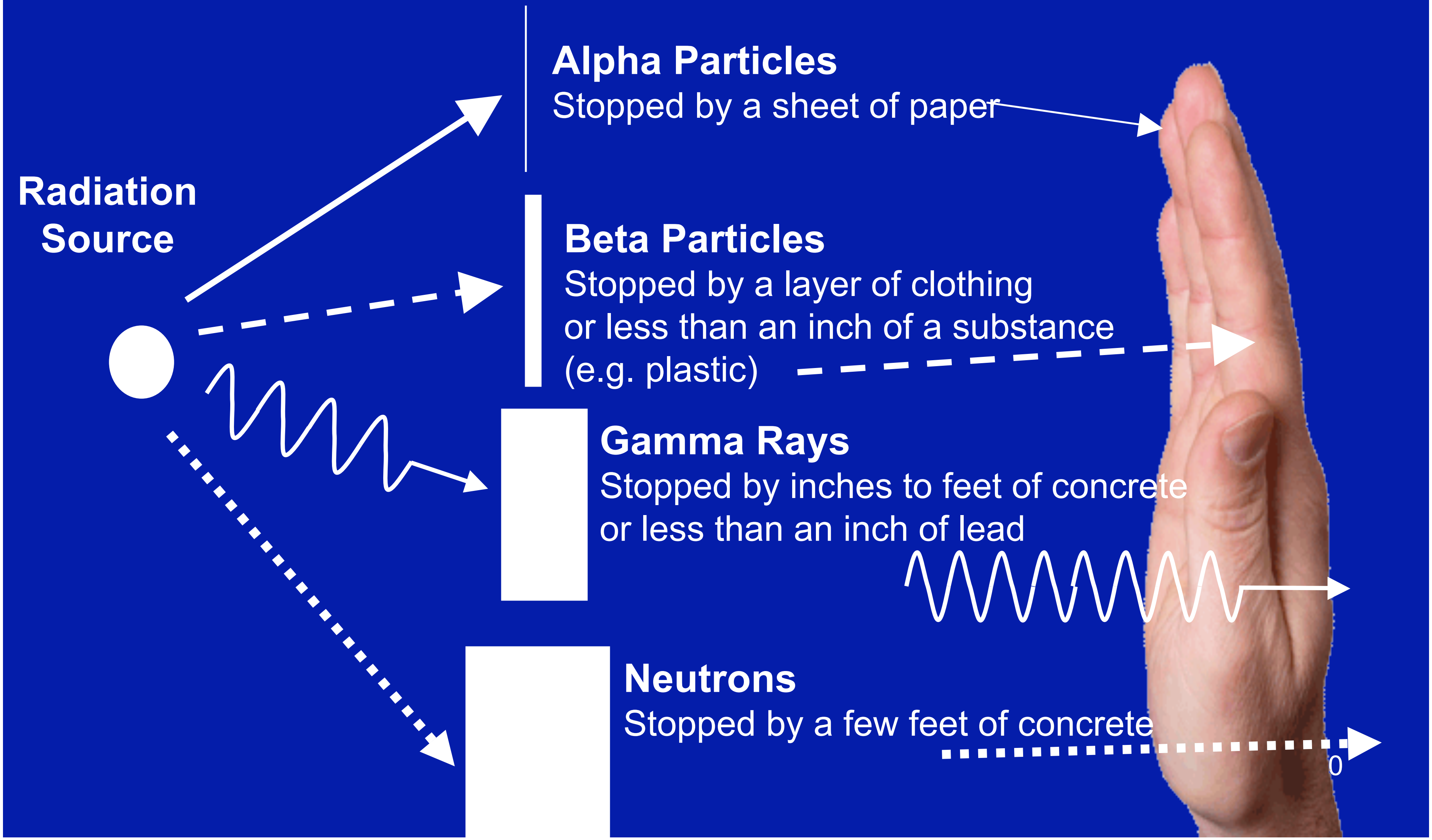
Beta Particle (β)



Gamma Ray (γ)

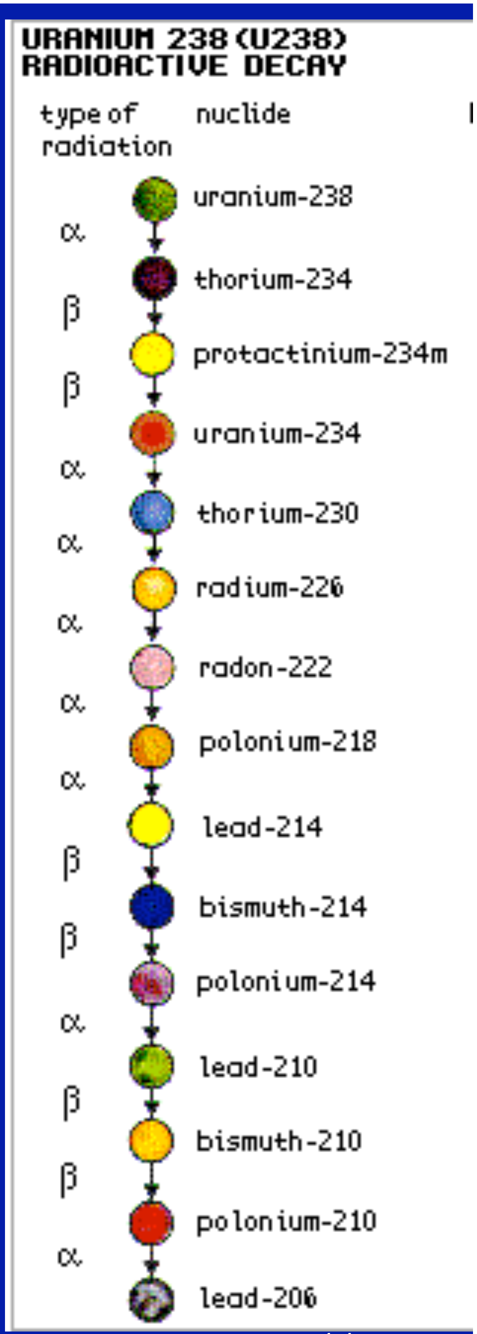


Penetration of Different Types of Radiation



Unstable Atoms Decay

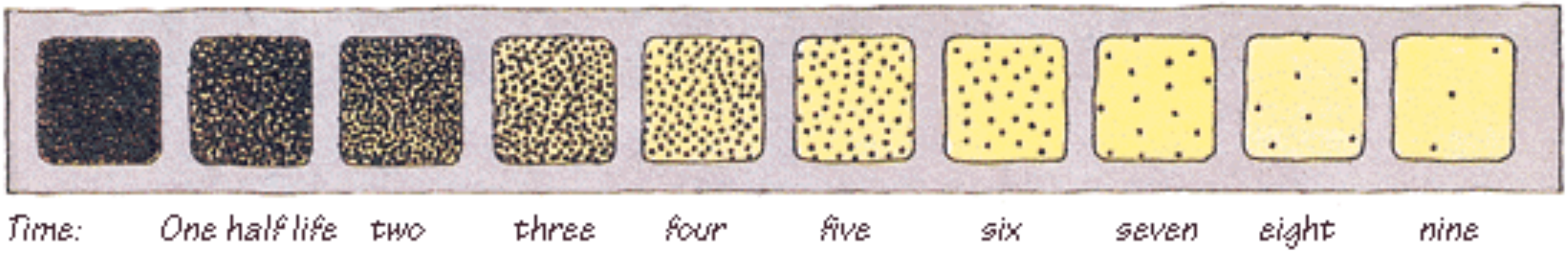
- The number of “decays” that occur per unit time in the radioactive material tell us how radioactive it is.
  - Units include Curies (Ci), decays per minute (dpm), and Becquerels (decays per second).
- When an unstable atom decays, it ***transforms*** into another atom and releases its excess energy in the form of radiation.
- Sometimes the new atom is also unstable, creating a “decay chain”



How Unstable Is It?

- The "Half-Life" describes how quickly Radioactive Material decays away with time. It is the time required for **half** of the unstable atoms to decay.
- Some Examples:
  - Some natural isotopes (like uranium and thorium) have half-lives that are billions of years,
  - Most medical isotopes (like Technicium-99m) last only a few days

Decay rate of radioactivity: After ten half lives, the level of radiation is reduced to one thousandth



Some Isotopes & Their Half Lives

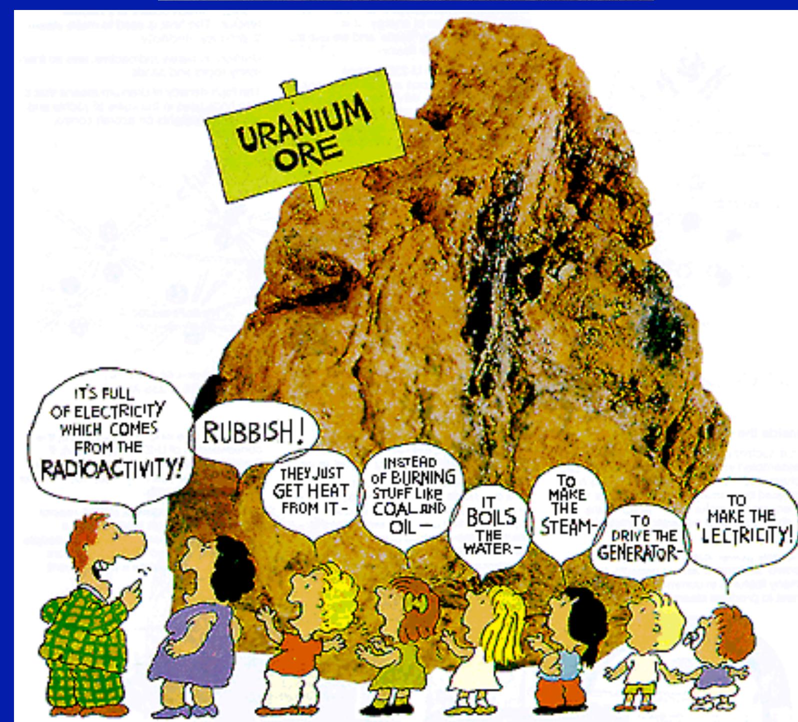
ISOTOPE	HALF-LIFE	APPLICATIONS
Uranium	**billions of years**	Natural uranium is comprised of several different isotopes. When enriched in the isotope of U-235, it's used to power nuclear reactor or nuclear weapons.
Carbon-14	**5730 y**	Found in nature from cosmic interactions, used to "carbon date" items and as radiolabel for detection of tumors.
Cesium-137	**30.2 y**	Blood irradiators, tumor treatment through external exposure. Also used for industrial radiography.
Hydrogen-3	**12.3 y**	Labeling biological tracers.
Irridium-192	**74 d**	Implants or "seeds" for treatment of cancer. Also used for industrial radiography.

The Amount of Radioactivity is NOT Necessarily Related to Size

- Specific activity is the amount of radioactivity found in a gram of material.

- Radioactive material with <u>long half-lives</u> have <u>low specific activity</u>.

<u>1 gram</u> of Cobalt-60
has the same activity as
<u>1800 tons</u> of natural Uranium



What is a “Dose” of Radiation?

- The more energy deposited into the body, the higher the dose.
- **Rem** is a unit of measure for radiation dose.
- When radiation’s energy is deposited into our body’s tissues, that is <u>a dose</u> of radiation.
- Small doses expressed in **mrem = 1/1000 rem**.
- **Rad & R** (Roentgens) are similar units that are often equated to the Rem.

Activity and Dose

Activity (amount of radioactive material)	Curie (Ci) $3.7x10^{10}$dps Becquerel (Bq) 1dps
Exposure (in air)	Roentgen
Absorbed dose	Rad
Dose Equivalent	Rem

Dose equivalent (H_T)

Dose equivalent (H_T) means the product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest.

The unit of dose equivalent is the rem

Quality Factor

- 1 for beta and gamma
- 20 for alpha

Committed dose equivalent (H_T,50)

- *Committed dose equivalent* (H_T,50) (CDE) means the dose equivalent to organs or tissues of reference (T) that will be received from an intake of radioactive material by an individual during the 50-year period following the intake.

Total Effective Dose Equivalent

- Total Effective Dose Equivalent (TEDE) is the sum of the external dose equivalent and the committed effective dose equivalent

Comparative Risk

Source	Lifetime Cancer Risk
5 rems (annual worker limit)	**$\sim 4 \times 10^{-3}$**
Smoking Tobacco	$\sim 1 \times 10^{-1}$
Industrial Chemicals (bkg)	$\sim 1.4 \times 10^{-3}$
Indoor Radon	$\sim 2 \times 10^{-3}$ nonsmokers $\sim 1 \times 10^{-2}$ smokers
Other Background Radiation (minus Radon) for 70 years	$\sim 9 \times 10^{-3}$

Typical Doses

Average Dose to US Public from All sources	360 mrem/year
Average Dose to US Public From Natural Sources	300 mrem/year
Average Dose to US Public From Medical Uses	53 mrem/year
Coal Burning Power Plant	0.2 mrem/year
Average dose to US Public from Weapons Fallout	< 1 mrem/year
Average Dose to US Public From Nuclear Power	< 0.1 mrem/year
Occupational Dose Limit for Radiation Workers	5,000 mrem/yr

Coast to coast Airplane roundtrip	5 mrem
Chest X ray	8 mrem
Dental X ray	10 mrem
Head/neck X ray	20 mrem
Shoe Fitting Fluoroscope (not in use now)	170 mrem
CT (head and body)	1,100 mrem
Therapeutic thyroid treatment (dose to the whole body)	7,000 mrem

Types of Exposure & Health Effects

- **Acute Dose**
  - Large radiation dose in a short period of time
  - Large doses may result in observable health effects
    - Early: Nausea & vomiting
    - Hair loss, fatigue, & medical complications
    - Burns and wounds heal slowly
  - Examples: medical exposures and accidental exposure to sealed sources

- **Chronic Dose**
  - Radiation dose received over a long period of time
  - Body more easily repairs damage from chronic doses
  - Does not usually result in observable effects
  - Examples: Background Radiation and Internal Deposition

At HIGH Doses, We KNOW Radiation Causes Harm

- High Dose effects seen in:
  - Radium dial painters
  - Early radiologists
  - Atomic bomb survivors
  - Populations near Chernobyl
  - Medical treatments
  - Criticality Accidents
- In addition to radiation sickness, increased cancer rates were also evident from high level exposures.

Effects of ACUTE Exposures

Dose (Rads*)	Effects
25-50	First sign of physical effects (drop in white blood cell count)
100	Threshold for vomiting (within a few hours of exposure)
320 - 360	~ 50% die within 60 days (with minimal supportive care)
480 - 540	~50 % die within 60 days (with supportive medical care)
1,000	~ 100% die within 30 days

* For common external exposures 1 Rad ~ 1Rem = 1,000 mrem

Long-term Effects of Radiation

- **Radiation is assumed to increase one's risk of cancer**
  - The "normal" chance of dying of cancer is ~ 23% (~460 out of 2,000).
  - Each rem is assumed to increase that risk by 0.05% (~1 chance in 2,000).

The occupational radiation dose limit to the whole body is 5 rem/yr (OSHA)

EPA (SHEM) Guidelines

- EPA has an Administrative Control Level (ACL) of 500 millirems per year

  - ACL is based on optimization using historical EPA worker dose data

  - ACL is not based on a safety threshold

  - All EPA workers receiving routine exposures above background must have training, wear TLDs and comply with EPA's Safety, Health and Environmental Management Program (SHEM Guidelines, Sec. 38)

SHEM Guidelines

- Waivers to the ACL should be obtained before, or if time-critical, *soon after* the ACL is exceeded from (in priority order)

  - *The EPA worker at risk of exposure*
  - *The senior EPA official in charge of operations at site*
  - *Locally responsible Regional Radiation Program Manager (RRPM) or RSO and SHEMP Manager*
  - *The workers' Assistant Administrator, Assistant Regional Administrator, or Lab Director as applicable.*

Detecting and Measuring Radiation

The Only Way To Travel!

Detecting Radiation

Alpha Survey Meter

Beta and Gamma Survey Meter

Eberline RO-20

(Ion Chamber)

SE Int’l Monitor 4
(Internal GM)

Eberline PIC 6B
(Pressurized Ion Chamber)

Bicron MicroRem(Plastic
Scintillator)

Ludlum Model 3(External
Detector)

Eberline HP-270
Side Wall probe

Ludlum 44-9 “Pancake” Probe

Ludlum 44-7End Window

Ludlum 44-3 probe

Eberline AC-3 Alpha Scintillator

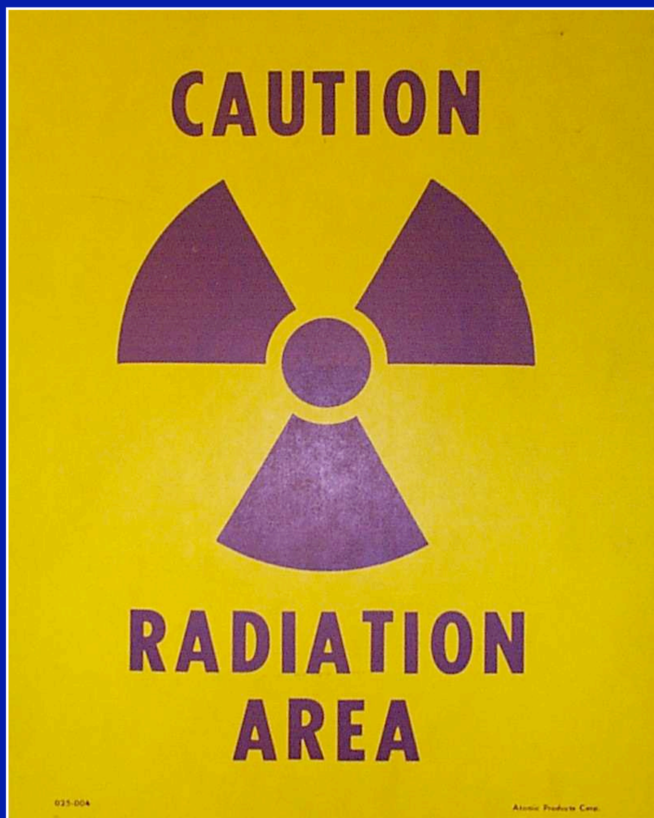
Ludlum 43-68 Gas Proportional Detector

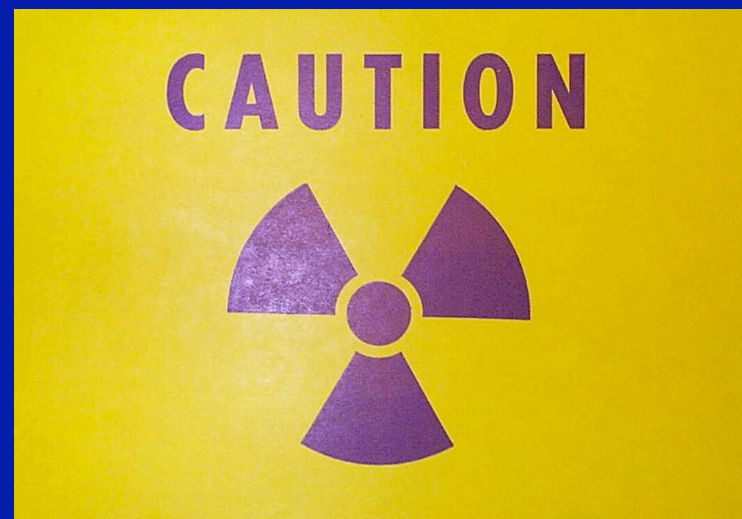
Hazard Awareness

- Ionizing radiation may be an easy hazard to detect (i.e., your rad meter starts clicking), but it may not be the only hazard associated with a site
  - Chemicals
  - Tripping hazards

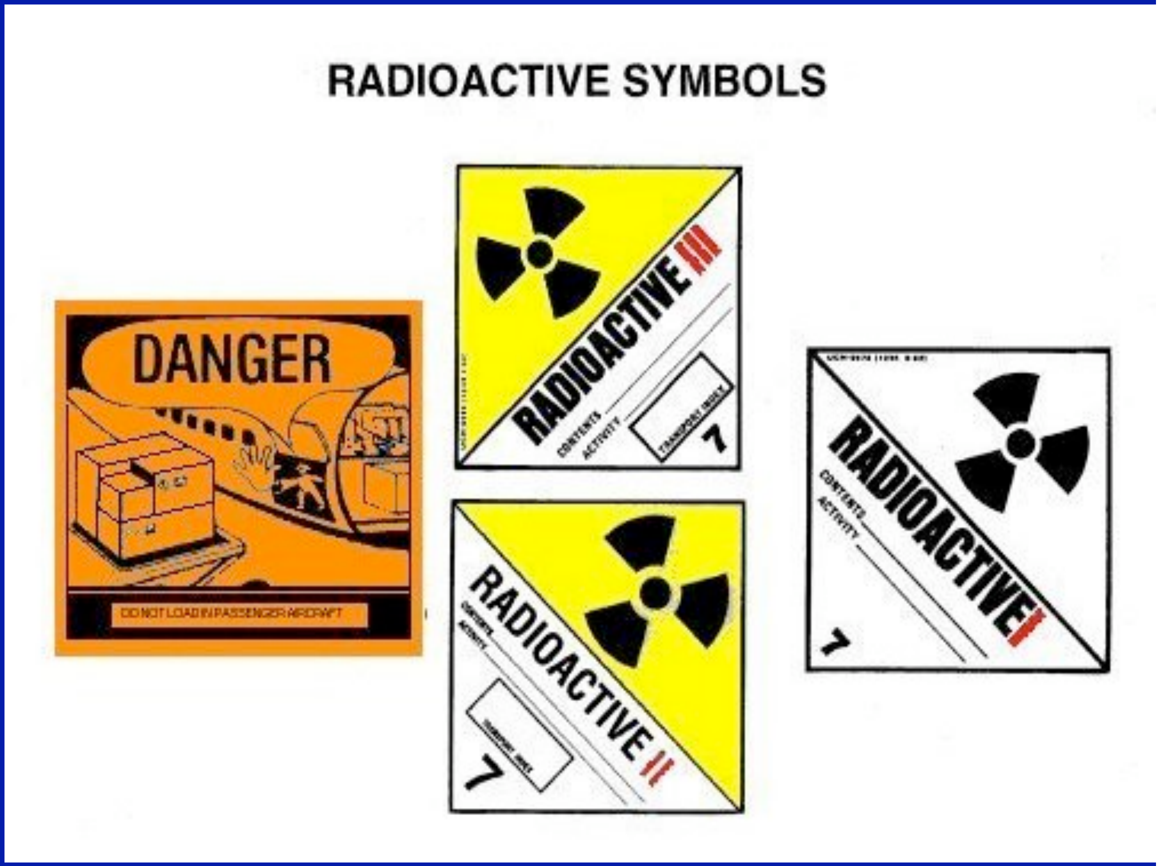
- If you find radiation, find a health physicist!
- Each region has one or more

Radiation Signs





Radiation Signs

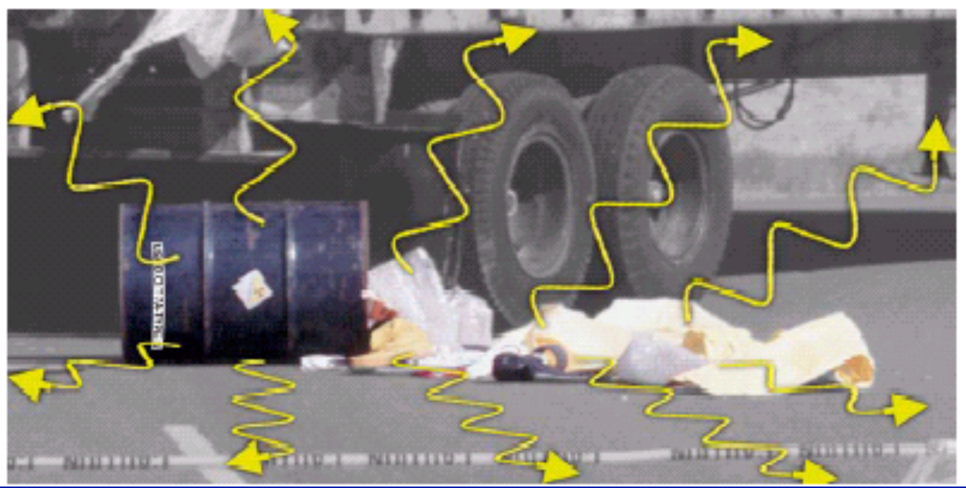


Protecting Yourself from Ionizing Radiation

External vs. Internal Hazards

- You don’t have to be in physical contact with gamma or beta radiation sources to be harmed
- Gamma radiation can even harm you when the source is fully contained
- Beta radiation can cause burns if left in contact with exposed skin
- All radioactivity, but particularly alpha, is harmful if inhaled or swallowed

Radiation vs Contamination



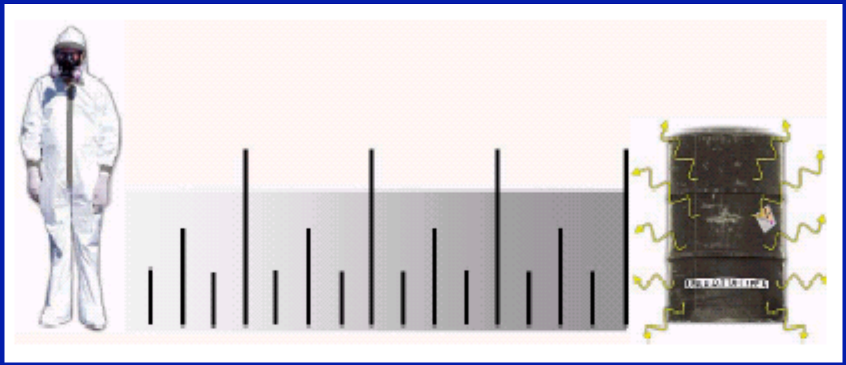
Wear appropriate PPE.

Select level for the circumstances

For external hazards,
remember three words:
Time, Distance, Shielding

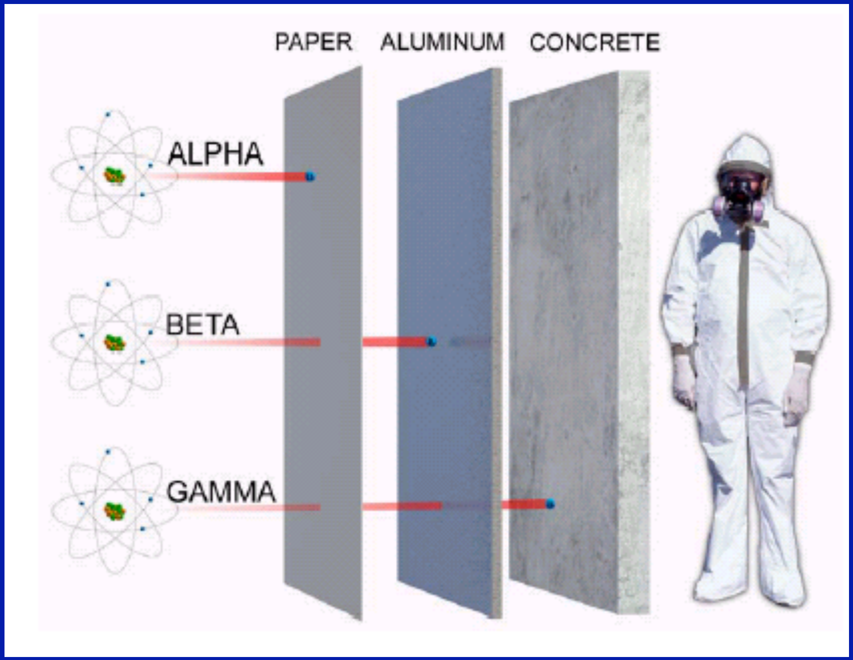
Minimize your time near the source!

Keep as much distance between you and the source as possible*.



*Tip: Teletectors (telescoping detectors) allow you to take rad readings at a greater distance from a source.

Use appropriate shielding when available*.



*Tip: Use what you have available.

Use an appropriate meter!

(good idea to bag it in contaminated areas, except for alpha detectors since plastic blocks alpha)

The meter must respond to and measure the type of radiation that is present

Plan If You Can

- Evaluate the risk beforehand
- Don’t charge into harm’s way without a clear purpose in mind
- Don’t take *unnecessary* measurements or samples at the expense of raising your radiation dose
- Even in an emergency, ALARA applies (as low as reasonably achievable)

Regional Radiation Contact

- Anthony Honnellio (R1) – 617-918-1456
- Paul Giardina (R2) – 212-637-4010
- Cristina Fernandez (R3) – 215-814-2178
- Rick Button (R4) – 404-562-9135
- Jack Barnette (R5) – 312-866-6175

Regional Radiation Contact

- George Brozowski (R6) – 214-665-8541
- Robert Dye (R7) – 913-551-7605
- Richard Graham (R8) – 303-312-7080
- Mike Bandrowski (R9) – 415-947-4194
- Rick Poeton (R10) – 206-553-8633